

Dent, and used by him for finding the longitudes of several observatories in this country.

On testing 100 chronometers in succession as they passed through the Observatory, the average alteration of daily rate caused by changing the temperature from 40° to 60° was $7^{\text{s}}.0$; and in ten per cent. of the hundred the average change was $30^{\text{s}}.6$.

The chronometer-room at the new Observatory now being erected at Bidston by the Mersey Docks and Harbour Board will be provided with the means of testing simultaneously between two and three hundred chronometers in the way shown by the examples in Table I. It is not necessary to test chronometers in this elaborate way on every occasion that they arrive in port, as the corrections for change of temperature remain the same for a long period. The *rate* may change, as in example 2, Table IV., while the thermal correction remains sensibly the same.

When the Greenwich mean time is communicated from an authorized establishment, as is now generally the case in our large sea-ports, the rates of chronometers in the temperature that prevails at the time can be easily ascertained. At present these rates are used on the assumption that the thermal adjustments are perfect. The corrections for change of temperature in Table II. show the improvement which might be effected by testing all chronometers when new, and supplying mariners with Tables of such corrections as may be found to exist. These corrections would require verifying periodically, as in cleaning and repairing timekeepers the thermal adjustment is sometimes altered.

December 21, 1865.

Sir HENRY HOLLAND, Bart., Vice-President, in the Chair.

The following communications were read:—

- I. “On the Expansion of Water and Mercury.” By A. MATTHIESSEN, F.R.S. Received December 7, 1865.

(Abstract.)

Before commencing a research into the expansion of the metals and their alloys, it was necessary to prove that the method I intended to employ, namely that of weighing the metal or alloy in water at different temperatures, would yield good and reliable results.

To check, therefore, the method, I was led to determine the coefficient of expansion of mercury, and, basing my calculations on Kopp’s coefficients of expansion of water, I expected to obtain Regnault’s coefficient of expansion of mercury. The coefficient deduced from experiments did not agree with Regnault’s; and being unable to discover any source of error in the method of experimenting, I determined to reinvestigate the matter.

The memoir is divided into four parts.

I. On the determination of the coefficients of the linear expansion of certain glass rods.

These rods (1825 millims. long and of 20 millims. diameter) were kindly made for these experiments by Mr. F. Osler. The method used for the determination of their increment in length was that of measuring it with a micrometer-screw, with which a length could be measured with accuracy to 0.001 millim.

The rod was placed in a long trough, the one end of the rod resting against a fixed glass tube capped with zinc, the other against another glass tube the other end of which rested against the micrometer-screw. Water was allowed to flow through these glass tubes during the time of observation. The trough being filled with water at ordinary temperature and the position of the screw read off, the water was heated to boiling and another reading taken.

The mean of sixteen observations gave for the linear expansion of these rods

$$L_t = L_0 (1 + 0.00000729t),$$

and therefore for the cubical expansion

$$V_t = V_0 (1 + 0.00002187t).$$

II. On the method employed for the determination of the cubical expansion of water and mercury.

This part of the paper contains a full description of the apparatus employed, and the precautions taken.

The method consists of weighing the substances in water at different temperatures, and from the loss of weight in water deducing its volume. For this deduction, the expansion of water at different temperatures is required.

III. On the redeterminations of the coefficients of expansion of water.

To determine these, pieces of the glass rods (the linear expansion of which had to be determined), ground to the shape of a double wedge, were weighed in water of different temperatures. Three pieces of glass were used (making three Series), the weighings being made at temperatures between 0° and 100°, the whole number of observations being thirty-two.

From these it was found that the expansion of water between 4° and 100° may conveniently be expressed between 4° and 32° by the formula

$$V_t = 1 - 0.0000025300(t-4) + 0.0000083890(t-4)^2 - 0.00000007173(t-4)^3,$$

and between 32° and 100° by

$$V_t = 0.999695 + 0.0000054724t^2 - 0.000000011260t^3.$$

The values calculated from these formulæ for the volume occupied by water at different temperatures are given in Table I. from degree to degree, together with the differences for each degree.

TABLE I.

T°. C.	Volume of water at T°.	Differ- ence per 1°.	T°. C.	Volume of water at T°.	Differ- ence per 1°.	T°. C.	Volume of water at T°.	Differ- ence per 1°.
4	1'000000	0'000006	37	1'006616	0'000355	69	1'022050	0'000598
5	1'000006		38	1'006979	363	70	1'022648	
6	1'000028		39	1'007351	372	71	1'023252	
7	1'000066	38	40	1'007730	379	72	1'023861	609
8	1'000119	53	41	1'008118	388	73	1'024477	616
9	1'000188	69	42	1'008514	396	74	1'025099	622
10	1'000271	83	43	1'008918	404	75	1'025727	628
11	1'000369	98	44	1'009331	413	76	1'026361	634
12	1'000479	110	45	1'009751	420	77	1'027000	639
13	1'000604	125	46	1'010179	428	78	1'027646	646
14	1'000742	138	47	1'010614	435	79	1'028296	650
15	1'000892	150	48	1'011059	445	80	1'028953	657
16	1'001054	162	49	1'011510	451	81	1'029615	662
17	1'001227	173	50	1'011969	459	82	1'030283	668
18	1'001412	185	51	1'012435	466	83	1'030956	673
19	1'001608	196	52	1'012909	474	84	1'031634	678
20	1'001814	206	53	1'013391	482	85	1'032318	684
21	1'002029	215	54	1'013879	488	86	1'033007	689
22	1'002254	225	55	1'014376	497	87	1'033701	694
23	1'002488	234	56	1'014879	503	88	1'034400	699
24	1'002731	243	57	1'015390	511	89	1'035104	704
25	1'002982	251	58	1'015907	517	90	1'035813	709
26	1'003241	259	59	1'016432	525	91	1'036527	714
27	1'003507	266	60	1'016964	532	92	1'037245	718
28	1'003780	273	61	1'017502	538	93	1'037969	724
29	1'004059	279	62	1'018047	545	94	1'038697	728
30	1'004345	286	63	1'018599	552	95	1'039429	732
31	1'004635	290	64	1'019158	559	96	1'040166	737
32	1'004931	296	65	1'019724	566	97	1'040907	741
33	1'005249	318	66	1'020296	572	98	1'041653	746
34	1'005578	329	67	1'020874	578	99	1'042404	751
35	1'005916	338	68	1'021459	585	100	1'043159	755
36	1'006261	0'000345			0'000591			

IV. On the redetermination of the coefficient of expansion of mercury.

The pure mercury was weighed in a bucket in the water at different temperatures. The glass bucket was made from the end of a test-tube (its length being about 20 millims. and width 15 millims.). The expansion of this sort of glass was found to be

$$V_t = V_0 (1 + 0.00002566t).$$

Five series were made with mercury; and its expansions, deduced from the water-expansions given in Table I, were

$$\text{Series I.} \dots\dots V_t = V_0 (1 + 0.0001815t),$$

$$\text{Series II.} \dots\dots V_t = V_0 (1 + 0.0001813t),$$

$$\text{Series III.} \dots\dots V_t = V_0 (1 + 0.0001808t),$$

$$\text{Series IV.} \dots\dots V_t = V_0 (1 + 0.0001808t),$$

$$\text{Series V.} \dots\dots V_t = V_0 (1 + 0.0001816t),$$

$$\text{Mean} \dots\dots V_t = V_0 (1 + 0.0001812t),$$

a value closely agreeing with Regnault's, namely

$$V = V_0 (1 + 0.0001815t).$$

Calculating from the five series the coefficients of expansion of mercury, using Kopp's water-expansion (taking the volume at $4^{\circ}=1$), we find as mean

$$V_t = V_0 (1 + 0.000178t).$$

In the following Table I give the values obtained by different observers for the volumes occupied by water at different temperatures, the volume at 4° being taken equal to 1.

TABLE II.

T.	p*.	Despretz †.	Pierre ‡.	Hagen §.	Matthiessen.
0	1.000000	1.000000	1.000000	1.000000	1.000000
4	1.000247	1.000268	1.000271	1.000269	1.000271
10	1.000818	1.000875	1.000850	1.000849	1.000892
15	1.001690	1.001790	1.001717	1.001721	1.001814
20	1.004187	1.004330	1.004195	1.004250	1.004345
30	1.007654	1.007730	1.007636	1.007711	1.007730
40	1.011890	1.012050	1.011939	1.011994	1.011969
50	1.016715	1.016980	1.017243	1.017001	1.016964
60	1.022371	1.022550	1.023064	1.022675	1.022648
70	1.028707	1.028850	1.029486	1.028932	1.028953
80	1.035524	1.035660	1.036421	1.035715	1.035813
90	1.043114	1.043150	1.043777	1.042969	1.043159
100					

Kopp, Despretz, and Pierre used the same method for their determinations—that of determining the expansion of water in glass vessels (dilatometers). Hagen employed the weighing process, but at high temperatures employed no special precautions to prevent the steam condensing on his fine wire; hence his values at 90° and 100° fall below mine.

It will be seen from the foregoing Table that Kopp's values are lower than the others; and bearing in mind that the coefficient of expansion of mercury, when deduced by means of these, falls below that obtained by Regnault, but when deduced from Despretz's or my own agrees closely with Regnault's, we are led to conclude that Kopp's values must be somewhat incorrect.

* Pogg. Ann. xcii. 42.

† Ann. de Chim. et de Phys. lxx. (1^{re} sér.) 1.

‡ Ann. de Chim. et de Phys. xiii. (3^{me} sér.) 325. Calculated by Frankenheim, Pogg. Ann. xvi. 451.

§ Abhandlungen d. k. Acad. der Wissensch. zu Berlin, 1865.